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SYRUS: Understanding and Predicting Multitasking Performance

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14. ABSTRACT

This report is organized as follows: First, a broad definition of multitasking performance is offered and important considerations related to this definition. Second, an outline of the many task and environmental characteristics that potentially influence multitasking performance in critical ways is suggested. Third, specific cognitive and non-cognitive variables are identified as prime candidates for predicting multitasking performance, and specific research-based predictions follow. Fourth, related to the previous point, a summarization of our initial empirical work on multitasking, based on college-student participants who engaged in a computerized multitasking performance task. Fifth, we conclude by suggesting several avenues that may be profitable for conducting future research on multitasking performance.

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Foreword

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SYRUS: Understanding and Predicting Multitasking Performance

As indicated by a recent Google® search with over 8,700,000 hits, *multitasking* is clearly a term in popular use these days, perhaps because the term increasingly captures the type of work and home environments found in modern society. The term also surfaces in the organizational research literature, often within the paradigm of a "changing world of work" (e.g., Ilgen & Pulakos, 1999), and in the cognitive psychology literature when discussing limitations or bottlenecks in human information processing (e.g., Tombu & Jolicoeur, 2005). But regardless of whether the context of a discussion on multitasking is colloquial or academic, the term appears to carry multiple definitions and therefore multiple implications as well. In some instances, multitasking implies cases where individuals are navigating the *chaos* of a situation. Cooking breakfast while watching a snippet of a news program on TV and holding a conversation with your children before they take the bus to school— all more or less at the same time —might be one example to which you can relate. In other instances, multitasking can imply the goal of *efficiency* in producing desired outcomes: A person answering e-mails and phone calls simultaneously may hope to perform more work in a given day than performing both tasks one at a time in serial order. Finally, multitasking can be thought of as a *trait*: some people seem to perform consistently well across a variety of multitasking situations, while others tend not to perform well at all and may benefit more from training interventions tailored to a specific problem. Our work is broader than any one definition or perspective on multitasking; it attempts to create a larger theoretical framework that encapsulates both individual and situational characteristics as they relate to multitasking, because in general, research evidences strong support for the influence of both individual and situational characteristics on human behavior (Hattrup & Jackson, 1996; Magnusson & Endler, 1977).

Organization of this Report

This report is organized as follows: First, we offer a broad definition of multitasking performance and raise important considerations related to this definition. Second, we outline the many task and environmental characteristics that potentially influence multitasking performance in critical ways. Third, specific cognitive and non-cognitive variables are identified as prime candidates for predicting multitasking performance, and specific research-based predictions follow. Fourth, related to the previous point, we summarize our initial empirical work on multitasking, based on college-student participants who engaged in a computerized multitasking performance task. Fifth, we conclude by suggesting several avenues that may be profitable for conducting future research on multitasking performance.

Toward a Definition of Multitasking

Our broad definition of multitasking performance is informed by several important contributions from the relevant literature on job performance in organizations, a literature that has made meaningful advances over the past 15 years. *Job performance* has been defined, and widely accepted by scholars in organizational research, as behaviors within an individual's control that make a direct contribution to outcomes relevant to the organization (Campbell, McCloy, Oppler, & Sager, 1993). Because this report is concerned with problem-solving performance of students, we apply this definition to grade point average (GPA), a common benchmark of student performance. GPA is a deficient measure with respect to this definition of job performance in two major ways. First, GPA tends to be a rather distal indicator of actual student performance (albeit a very important one). In other words, GPA is a performance measure that is subject to many factors out of a student's control, such as the variability with which the instructor assigns grades, the performance of a student relative to other students in a particular class, and the type of questions that the instructor decided to select for a test. To the extent that factors such as these affect different students or classrooms differently, GPA would be a distortion of actual levels of performance. Second, GPA by definition is an aggregate index, meaning it is possible that two students obtaining the same GPA underwent completely different routes in getting there. GPA is thus a global indicator of student performance that is likely to mask important processes related to actual student performance and problem-solving behavior. Both of the aforementioned deficiencies apply to almost any other measure of performance, too, such as supervisory ratings of job performance. In a Navy setting it is only a short leap to extrapolate this concept to officer fitness reports and enlisted performance evaluations.

Although it may never be possible to eliminate deficiencies such as these entirely, we have remained mindful of them in selecting our own measures of multitasking performance and analyzing data from them. It is important to acknowledge that external factors out of the individual's control may affect measures of multitasking performance, and these factors are distinct from multitasking performance itself. To the extent such factors *interact* with individual multitasking performance, they should be measured and empirically taken into consideration. Additionally, although our program of research on multitasking performance is in its infant stages, it seeks to achieve a greater understanding of behavioral processes, and although any practical and useful measure of multitasking performance may out of necessity reflect an aggregate of individual behaviors, it cannot aggregate too much without potentially sacrificing valuable information regarding these processes.

Determinants of Multitasking Performance

In addition to past research defining job performance as being tied directly to individual behavior, performance has been defined as a function of three—and only three—determinants (see Campbell, Gasser, & Oswald, 1996). These also apply to multitasking performance in a straightforward manner. The first determinant, *declarative knowledge,* refers to an individual's storehouse of performance-relevant

facts, whereas the second determinant, *procedural knowledge,* refers to an individual's past behaviors that are related to performance, either directly or indirectly. Although declarative knowledge contains the building blocks for procedural knowledge, skilled performers who have procedural knowledge may not be able to articulate the declarative knowledge that contributes to their performance; they only do so retrospectively when asked, but not while actually performing (e.g., children who can snow ski, calculating prodigies who can instantly take cube roots of numbers). The third determinant, *motivation,* comprises the direction, frequency, and intensity of performance-related behavior. We know that high-school students, for example, vary widely in their motivation levels. At any given point in time, students can choose to engage in solving a problem-solving task—or they can choose not to (direction). Across time, students can choose to revisit a task and keep working to make progress on it—or they can choose not to (frequency); and even when students are engaged in a task, they can concentrate and work hard on it—or they can choose not to (intensity). If it is an axiom that performance reflects behaviors in control of the individual, then changes over time must occur through a shift in these three determinants. For instance, declarative knowledge can surge when individuals undergo formal training, procedural knowledge can be shaped implicitly through feedback comprising performance successes and failures over time, and motivation can increase (or be reduced) by observing the performance of similar peers.

Defining Multitasking Performance

Refined definitions of job performance are relatively recent in the organizational literature, at least compared with the century-long scientific interest in complex problem solving within workplace settings. Hugo Münsterberg, one of the forefathers of organizational psychology, was interested in individual differences as predictors of accidents in electric streetcar operators. In his creation of one of the first work simulations in an experimental setting, for use in personnel selection, he notes:

> The test of the method lies first in the fact that the tried motormen agreed that they really pass through the experiment with the feeling which they have on their car. The necessity of looking out in both directions, right and left, for possible obstacles, of distinguishing those which move toward the track from the many which move along the track, the quick discrimination among the various rates of rapidity, the steady forward movement of the observation point, the constant temptation to give attention to those which are still too far away or to those which are so near that they will cross the track before the approach of the car, in short, the whole complex situation with its demands on attention, imagination, and quick adjustment, soon brings them into an attitude which they themselves feel as identical with that in practical life. (Münsterberg, 1913, pp. 74–75).

We follow a long line of researchers who have demonstrated an interest in studying complex task performance, as we seek to understand and predict multitasking performance in real-world scenarios. We argue that evaluating whether a problem-solving or work environment is a multitasking environment involves gathering

information on three key points that are simple, but deceptively so. Acquiring information relevant to these three points may be quite difficult, but is well worth any time spent on them.

The first point is circular: multitasking *requires performing multiple tasks*. This is simple and tautological enough, but what is a task, and what is the most appropriate way to make distinctions between one task and another? We argue that task distinctions could be made on the basis of the following features, or some combination thereof: (1) the physical nature of the tasks (e.g., different equipment is used or different processes are involved); (2) the demands placed on individuals performing the tasks (e.g., different ability or personality characteristics are recruited by each task); (3) the outcomes of the tasks (e.g., performance outcomes on the tasks correlate less than 1.0 at the latent level); and (4) the performers' perceptions of the tasks as separable (e.g., expert performers might view many sub-tasks as one overall task, whereas novice performers may view the sub-tasks as separate tasks).

The second point is that multitasking performance does not simply require multiple tasks; *performance requires a conscious shifting from one task to another*. Tasks may appear simultaneous (e.g., listening to the radio while driving a car), but we argue that multitasking occurs when attention shifts across tasks. Whether such shifting is simple or difficult depends on the amount and type of attentional resources that are devoted to each task. Tasks that can be performed relatively automatically tend to rely on an individual's procedural knowledge and require fewer attentional resources (Ackerman, 1987; Hasher & Zacks, 1977); thus they are more amenable to multitasking than tasks that are unpredictable or whose rules are constantly changing.

The third point is that *performance on multiple tasks, with shifts in attention, must occur over a short time span*. The following information might be obtained to form a judgment about whether time span across which tasks are performed is short: (1) objective information, such as the length of time required in executing each task, by the intervals in between transitioning from one task to another, or by the number of instances per unit time that a performer returns to a specific task; and (2) subjective information, such as measures of individuals' perception of pace in moving from one task to another or by having incumbents with job experience rate the job environment comprising multiple tasks on whether performance requires multitasking ability.

Given these three points we feel are essential to a definition of multitasking, there are many nonessentials. Here are but a few examples:

- Multitasking individuals may or may not return to a task that was previously performed.
- They may not complete the tasks in which they are engaged, although of course, rewards for multitasking performance may often be contingent on completion of some or all of the tasks.
- Tasks may or may not accomplish the same goals. In fact, some tasks may be viewed as distractions that cannot be avoided (see Table 1).

- Individuals may perform tasks in what seems to be a simultaneous manner, particularly when they are cross-modal (e.g., visual and auditory; Wickens, Mountford, & Schreiner, 1981), or there may be more obvious shifting between tasks.

Table 1
Task features in individual multitasking performance

Task Characteristics
physical (modality, visual similarity)
psychological (pleasant, fatiguing)
complexity (simple vs. complex; detailed vs. general)
novelty (unique features, changing features)
Task Structure
number of tasks (many vs. few)
ordering (sequential vs. simultaneous)
interdependence (independent vs. interdependent)
importance of tasks (constant vs. variable importance; goal-relevant vs. distracting)
Task Timing
pace (self-driven vs. task-driven; predictable vs. unpredictable)
response demand (serial vs. parallel; alternating vs. random)
Task Control
task flexibility (able to be rearranged, restructured, or supplemented)
task execution (scripted vs. unscripted)
temporal presentation (simultaneous vs. serial)
task facilitators or limiters (e.g., signs or alarms that guide behavior, computer output that takes too long to read)
environmental facilitators or limiters (quiet vs. loud noise, adequate vs. dim lighting, no odors vs. strong odors)
Task Outcomes
feedback (content, structure, timing; specific task feedback or overall multitasking feedback)
reward (content, structure, timing; specific task reward or overall multitasking reward)

It is also theoretically interesting and practically important to note that the same multitasking situation can yield very different individual responses: What one person may perceive as interesting and exciting, another person may view as threatening and stressful. Empirical research could investigate how multitasking traits relate to a wide variety of important outcomes. For instance, individuals who enjoy—and thrive within—multitasking environments might deliberately construct their work and home environments to involve multitasking; conversely, individuals who tend to dislike and perform poorly at multitasking might instead structure their environments to facilitate

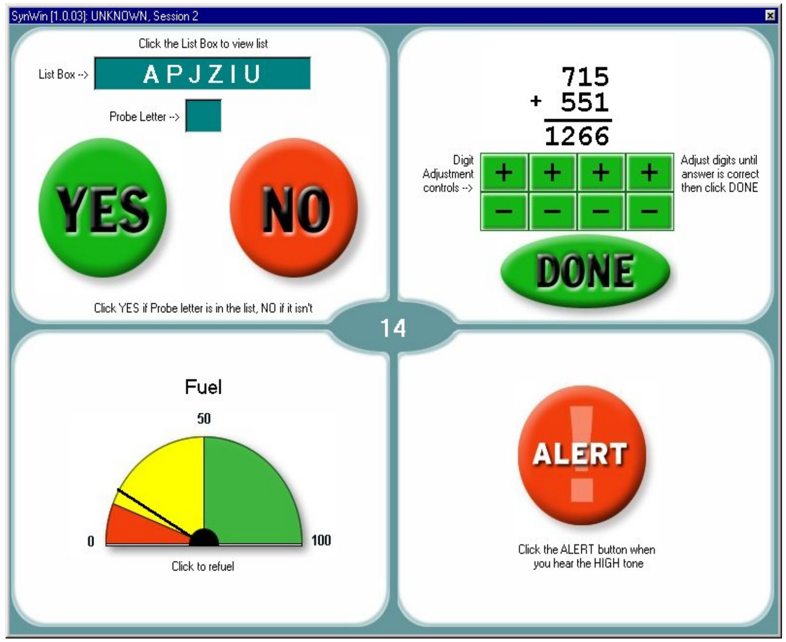
concentration and execution of one task at a time. Both experimental and correlational research could fruitfully bring empirical evidence to bear on questions such as this one whose answers can yield practical benefit in educational and employment settings.

Relating Multitasking to Ability, Personality, and Motivational Determinants

The remainder of this report describes some preliminary results that led to a program of research for the U.S. Navy. The ultimate aim of this research is to measure multitasking performance in high-fidelity simulations of Navy jobs, such as radar monitoring, and to identify and operationalize individual differences. However, as a starting point, we adopted a task that was designed by Elsmore (1994) to capture basic aspects of individual multitasking for many different jobs instead of a single job. This “synthetic” work task, illustrated in Figure 1, comprises four component tasks that are presented simultaneously. In *memory search* (upper left), a set of letters is presented and then covered, and participants then must verify whether periodically presented probe letters were from this set; clicking the mouse arrow on the cover reveals the letter set again, but doing so carries a point penalty. In *arithmetic*, participants are to add 2-digit or 3-digit numbers together correctly when their time permits. In *visual monitoring*, a needle moves from right to left across a gauge, and the task is to click on the gauge and reset the needle before it reaches zero; participants receive more points for the needle being as close to zero as possible, but they lose points proportional to the length of time the needs stays at zero. Finally, in *auditory monitoring*, the task is to respond to a higher-pitch target tone and to ignore a lower-pitch distracter tone. Obviously, synthetic work is not veridical with any real-world problem solving task. However, a key advantage from the standpoint of studying multitasking scientifically is that it is highly configurable, such that task difficulty and task payoffs can be flexibly altered, and the task requires no special skills or prior knowledge.

Memory	B	E
Rate	10s	5s
Correct	10	30
Incorrect	10	10

Arithmetic	B	E
Rate	–	–
Correct	20	20
Incorrect	10	10



Visual Monitoring	B	E
Rate	50s	25s
Correct	10	30
Incorrect	10	10

Auditory Monitoring	B	E
Rate	10s	5s
Correct	10	30
Incorrect	10	10

Figure 1. Synthetic Work: Tasks, rate and payoffs in baseline (B) and emergency (E) conditions.

Predictions

Research has established a strong relationship between performance in multitasking paradigms and performance in standard tests of intelligence. In fact, a number of researchers have concluded that multitasking ability is highly related to general intelligence (see Brookings, 1990). Research has further established a strong relationship between measures of general intelligence (g) and measures of working memory capacity, defined as the ability to store and process information simultaneously. In fact, research has suggested that working memory is the central component underlying variation in g (e.g., Engle & Kane, 2004). Results of a study by Kane et al. (2004) are illustrative. In this study, participants completed six "complex span" tasks to assess working memory capacity. Each task was essentially dual-task in nature. For example, in a task called reading span, each trial consisted of a sentence-word pair. The task was to verify whether the sentence makes sense and to remember the word. In addition, participants completed 12 tests of abstract reasoning and spatial visualization to assess psychometric g. Briefly, the major finding of this study was that a working memory factor comprising the six complex span tasks correlated strongly with a g factor ($r > .60$).

On the basis of this evidence, we predicted that measures of cognitive ability would positively predict synthetic work performance. Of more interest was the possible contribution of *non-ability* factors. Everyday observation suggests that one factor that may predict success in multitasking environments is the ability to keep a "cool head," particularly under time pressure. In more scientific terms, our speculation is that a critical determinant of multitasking success is the ability to effectively regulate *anxiety* or *arousal* during task performance. This speculation stems out of an extensive literature review documenting the relationship between arousal and complex task performance (see Proctor & Dutta, 1995, for a review). The basic finding from that body of research was captured by the Yerkes Dodson Law nearly 100 years ago: A "middle" level of arousal leads to optimal task performance; under-arousal and over-arousal lead to suboptimal task performance (Yerkes & Dodson, 1908; see Figure 2).

We therefore predicted that measures assumed to reflect anxiety would also emerge as significant predictors of multitasking performance. More specifically, we hypothesized that *neuroticism*, a broad dimension of personality that encompasses susceptibility to experiencing anxiety, would predict individuals' performance of the synthetic work task. An even more specific set of predictions that we tested was that neuroticism would be more predictive of multitasking performance under the "routine" condition than under the "emergency" condition. This may seem counterintuitive at first glance, but under "emergency" conditions, multitasking is made more difficult by greatly increasing the pace of the component tasks, and thus *everyone* should be more anxious when multitasking, not just those higher in neuroticism. Under "routine" conditions, the pace of multitasking is slower, which makes accomplishing the tasks more achievable, and therefore those who are more neurotic should show impaired

performance relative to those who are less neurotic. Thus, the correlation between neuroticism and performance should be negative in the “routine” condition and slightly negative or near-zero in the “emergency” condition.

The predictions just offered lay out the rationale for the empirical study that follows. However we should also point out that the ability and non-ability variables targeted for this study are part of a more general conceptual model for predicting multitasking performance. Figure 3 illustrates the model that we are in the process of developing further. Here the three major determinants of job performance reside at the center, serving as the theoretical glue between individual multitasking performance, the dependent variable of interest, and a complement of ability and non-ability variables that we have identified as theoretically relevant predictors. At its essence, our model is aligned with other integrative models of individual differences and performance that incorporate anxiety, motivation, personality and other non-cognitive factors as influences on complex task performance (e.g., Humphreys & Revelle, 1984; Kahneman, 1973; Kanfer & Ackerman, 1989); also, an empirical study of job performance supports a similar model (McCloy, Campbell, & Cudeck, 1994).

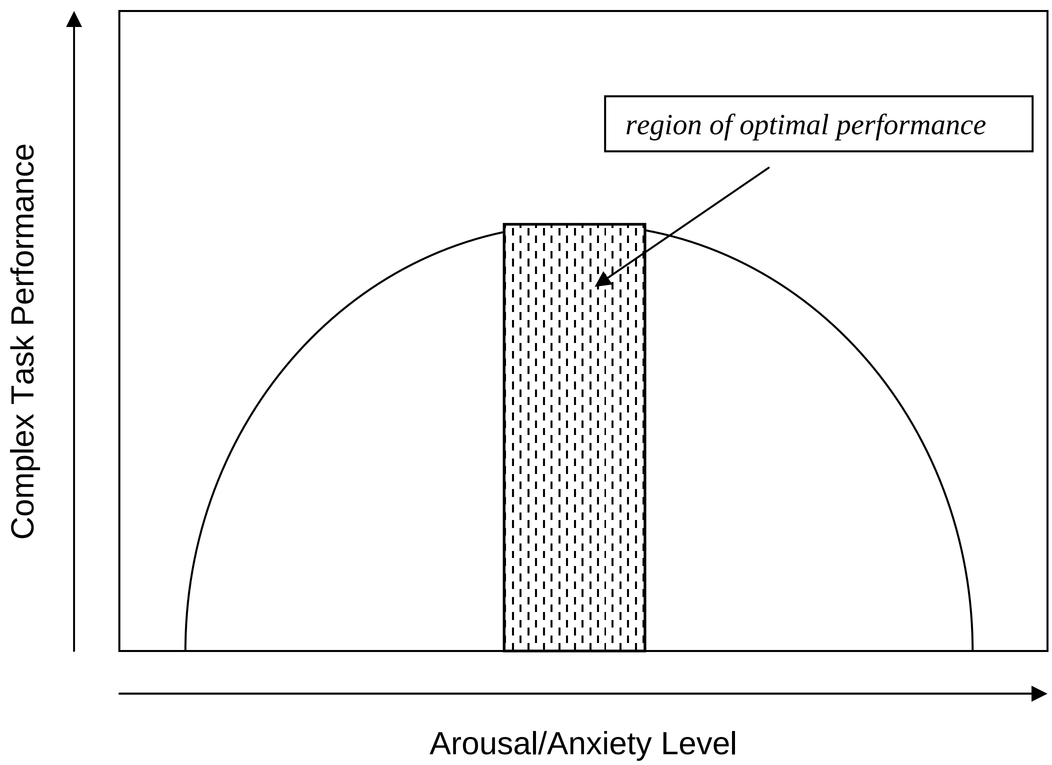


Figure 2. Hypothetical Anxiety-Performance relationship (Yerkes-Dodson Law).

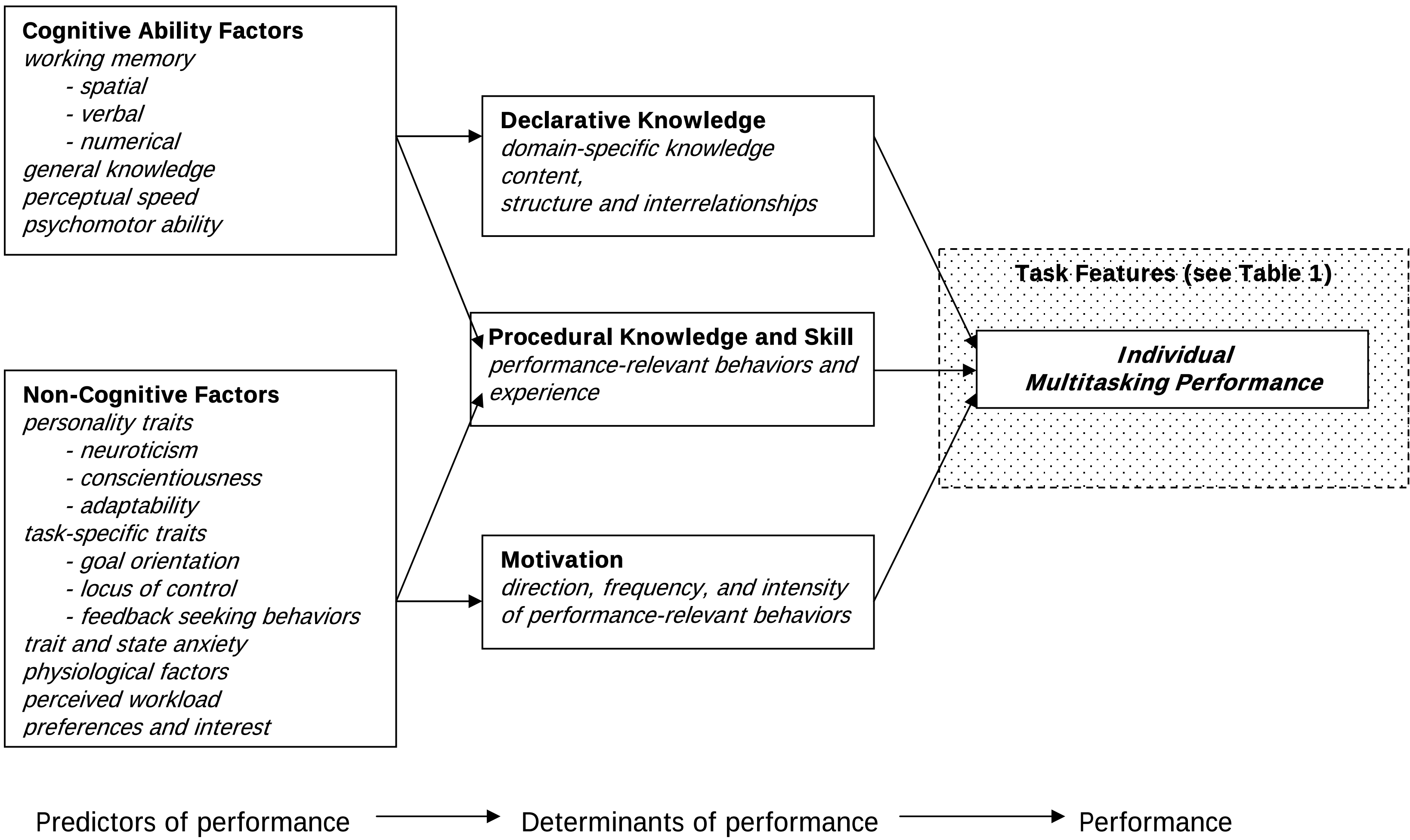


Figure 3. General conceptual model for individual multitasking performance.

Method

Participants

Participants were 125 undergraduate students recruited from introductory psychology courses at Michigan State University, who participated voluntarily in exchange for course credit. Sixty-eight percent were female, 40 percent were freshmen, 27 percent were sophomores, 27 percent were juniors, and 6 percent were seniors or more advanced students. The mean age was 19.1 years, but most students (68%) were between 18–19 years of age. Regarding ethnicity, 75 percent of the sample was non-Hispanic Caucasian, 10 percent Asian, 7 percent African-American, 4 percent Hispanic, with 4 percent classified as other/unidentified.

Materials and Procedure

Participants were tested in a laboratory setting in small proctored groups across two sessions, each session taking approximately 1.5 hours, and each session with small groups of 4–10 individuals being tested simultaneously. Tests and questionnaires relevant to the present chapter are as follows:

Session 1. In Session 1, after completing a demographic questionnaire, participants completed two working memory tasks. In *operation span*, participants were presented with equation-word pairs such as: "IS (12 / 3) + 3 = 6? DOG." For each pair like this, the task was to indicate whether the equation was correct or incorrect, and also to remember the word. After between two and six pairs were presented, a recall prompt appeared, and the task was to report the words in the order in which they appeared. In *symmetry span*, each trial consisted of a matrix, with some cells filled, followed by an arrow. The task was to judge whether the pattern in the matrix was symmetrical along the vertical axis, and then to remember the direction of each arrow. After between 2 and 6 pairs, a recall prompt appeared, and the task was to report the direction of the first arrow, the second arrow, and so forth.

After the working memory tasks, participants then completed two perceptual speed tasks. In *letter comparison*, stimuli were pairs of letters separated by a line such as "XJK ___ XRK." Participants were to write S on the line if the pairs were the same or D if they were different. In *pattern comparison*, the task was the same, except that the stimuli were geometric patterns. In both tasks, the goal was to make as many comparisons as possible in 30 seconds. Following these perceptual speed tasks were two abstract reasoning tests. In *matrix reasoning*, each item consisted of consisted of a 3 × 3 matrix in which each cell contained a pattern except the one in the lower right-hand corner; the task was to choose from among eight alternatives a pattern that made logical sense in the missing ninth cell. Eight minutes were allowed for 14 items. In *letter sets*, each item consisted of five sets of letters; the task was to infer the rule that made these letter sets similar and to identify the letter set that did not fit this rule. Eight minutes were allowed for 14 items.

Finally, following this set of cognitive tasks, participants completed 50 items from the International Personality Item Pool (IPIP) to measure 5 dimensions of personality: Neuroticism, Extraversion, Openness, Agreeableness, and Conscientiousness. Each item was a statement such as “I am the life of the party” or “I feel comfortable around people.” The participants’ task was to rate each item on how well it described them, using a 5-point scale.

Session 2. In Session 2, participants performed 9 5-minute blocks of the synthetic work task, called SynWin. Figure 1 illustrates the parameters for Blocks 1–5 (*baseline blocks*) and Blocks 6–9 (*emergency blocks*) are illustrated in Figure 2. As shown, in terms of points awarded for correct answers, the math task was emphasized in the baseline blocks, where by contrast the memory, auditory monitoring, and visual monitoring tasks were emphasized in the emergency blocks. It can also be seen that the overall pace of the task was faster in the baseline blocks than in the emergency blocks. Specifically, the inter-stimulus interval in the memory task and auditory task changed from 10 seconds to 5 seconds, and the pace of the needle in the visual monitoring task doubled, from 50 seconds to 25 seconds.

Results and Discussion

Table 2 displays correlations among the ability and personality predictor variables. As expected, the cognitive ability variables correlated positively with each other, and when the variables were entered into a factor analysis, the first principal component accounted for a large proportion of the variance (36.5%). Thus, we created a unit-weighted composite variable reflecting psychometric *g* by averaging the *z*-scores for the six variables. The pattern of correlations among the personality variables was in line with those found in previous research (De Fruyt & Mervielde, 1999)

Table 2
Correlations among ability and non-ability variables

	1	2	3	4	5	6	7	8	9	10	11
Ability											
1. Operation Span	–										
2. Symmetry Span	.37	–									
3. Letter Comparison	.14	.14	–								
4. Pattern Comparison	.23	.29	.39	–							
5. Matrix Reasoning	.27	.34	.15	.19	–						
6. Letter Sets	.32	.19	.27	.13	.11	–					
Personality											
7. Neuroticism	.05	.01	.07	.04	.01	-.07	–				
8. Extraversion	.04	.19	.03	.22	-.04	.05	-.27	–			
9. Openness	.16	.16	-.06	.25	.17	.08	-.18	.20	–		
10. Agreeableness	.08	.07	-.20	-.03	-.11	.14	-.16	.31	.18	–	
11. Conscientiousness	-.07	-.23	.00	-.07	-.09	-.03	-.14	.02	.02	.34	–

Note. Correlations with an absolute magnitude greater than .18 are statistically significant ($p < .05$).

Table 3 displays correlations among total scores from the nine synthetic work blocks. Not surprisingly, the correlations were uniformly positive: Participants who performed well in one block tended to perform well in the other blocks. However, it can also be seen that scores from baseline blocks (1–5) correlated more strongly with each other than with scores from the emergency blocks (6–9), and vice-versa. The implication of this finding is that there was a shift in factors underlying performance moving from the baseline blocks to the emergency blocks. To investigate this possibility more formally, we entered the synthetic work scores into a factor analysis. The criterion for factor extraction was the scree plot, and we rotated the two factors extracted to an oblique solution, allowing the factors to correlate. Results are displayed in Table 4. As shown, Factor 1 was clearly interpretable as *baseline performance* and Factor 2 as *emergency performance*. Furthermore, consistent with the possibility that different factors contributed to variance across the two major phases of the task, the factors correlated only moderately (r = .38).

Table 3
Correlations among total scores from Synthetic Work task

	1	2	3	4	5	6	7	8	9
Baseline Blocks									
1. Block 1	–								
2. Block 2	.85	–							
3. Block 3	.83	.93	–						
4. Block 4	.67	.78	.78	–					
5. Block 5	.44	.61	.63	.71	–				
Emergency Blocks									
6. Block 6	.30	.42	.37	.48	.40	–			
7. Block 7	.16	.31	.27	.35	.43	.80	–		
8. Block 8	.17	.26	.25	.34	.35	.75	.89	–	
9. Block 9	.12	.22	.19	.28	.39	.70	.85	.90	–

Note. Correlations with an absolute magnitude greater than .18 are statistically significant (p < .05). Baseline blocks (Blocks 1–5); Emergency blocks (Blocks 6–9).

Table 4
Factor analysis of Synthetic Work total scores

	Factor 1	Factor 2
Baseline Blocks		
Block 1	.87	-.12
Block 2	.98	-.03
Block 3	.98	-.06
Block 4	.81	.11
Block 5	.60	.20
Emergency Blocks		
Block 6	.19	.74
Block 7	.00	.95
Block 8	-.04	.97
Block 9	-.09	.94
Eigenvalue	5.02	2.43
% of Total Variance	56	27

Note. Pattern matrix is displayed from an oblimin solution, where Factor 1 and Factor 2 correlate .38. Salient loadings (> .30) are boldfaced.

Once this was established, we correlated baseline and emergency factor scores with the ability and non-ability variables described previously to see whether there was a shift in factors contributing to performance in the two phases. Results are displayed in Table 5. Confirming our first prediction, g was a positive predictor of performance under both conditions: Baseline (r = .25) and

Emergency (r = .36). Furthermore, confirming our second prediction, neuroticism emerged as a significant predictor of baseline performance (r = -.21). Individuals low in neuroticism tended to outperform individuals high in neuroticism. However, there was no evidence for an increased influence of neuroticism in the emergency blocks. In fact, neuroticism correlated essentially zero with emergency performance (r = -.03). There was, however, a significant *negative* correlation of conscientiousness with emergency performance (r = -.24), such that individuals high in conscientiousness tended to perform worse than individuals low in conscientiousness.

Table 5
Correlations of predictor variables with baseline performance vs. emergency performance

Performance Block	*g*	N	E	O	A	C
Baseline	*.25*	*-.21*	.01	.13	.01	.00
Emergency	*.36*	-.03	.02	*.17*	-.08	*-.24*

Note. g = general cognitive ability; N = Neuroticism; E = Extraversion; O = Openness; A = Agreeableness; C = Conscientiousness. Boldface and italics indicate statistical significance at p < .01, and italics only at p < .05.

Not surprisingly, cognitive ability correlated positively with our multitasking performance task. We can only speculate at this point about specific processes captured by our tests of cognitive ability that were the most important contributors to multitasking performance, but one possibility stems from the research perspective that working memory capacity is the central component underlying general intelligence (see Kyllonen, 1996). More specifically, our thinking is that success in multitasking depends critically on active maintenance of what might be termed *control information*. In our empirical study, consider the case of performing the arithmetic task and then being interrupted by an alarm coming from the auditory task. Given the view that working memory capacity reflects the capability to maintain task goals in an active state, particularly in the face of distraction or interference (Engle & Kane, 2004), then individuals with higher levels of working memory capacity should be better able to maintain the goal of returning to the arithmetic task (e.g., "Go back to math") while responding to the auditory task than individuals with lower levels of working memory capacity.

Additionally, empirical results presented here also suggest that important non-ability factors underlie success (or failure) in multitasking. Neuroticism correlated negatively with performance in the initial blocks of the task, and as already discussed, one possible explanation for this finding is that people higher in neuroticism are more likely to experience debilitating levels of anxiety during complex task performance than people lower in neuroticism. The correlation disappeared in our "emergency" condition, where the pace doubled; in this condition everyone was arguably a bit more anxious and hence neuroticism was not as much of a predictor of performance. In the non-ability domain, it is also

interesting to note the *negative* correlation we obtained between conscientiousness and performance during the emergency blocks of the task. What might explain this result? One somewhat counterintuitive possibility is that those scoring higher on the conscientiousness measure tend to be more careful and deliberate in their work, and these factors are actually detrimental to emergency task performance which demands quick, almost reflexive, responding.

Thus we conclude that the promise of non-ability factors in predicting multitasking performance has received empirical support in the present study. Moreover, the amount of variance predicted by non-ability factors meaningfully adds to the prediction offered by ability factors. More specifically, because ability and personality correlations were very small in our study (i.e., *g* and Conscientiousness correlated -.09, and *g* and Neuroticism correlated -.01, with both correlations statistically non-significant), the prediction offered by personality variables was not redundant. This conclusion is in line with Ackerman, Kanfer, and Goff (1995) in their prediction of performance on an air traffic controller task from personality and ability measures, and also that of Schmidt and Hunter (1998) whose meta-analytic results support incremental validity for measures of employee integrity, above and beyond measures of employee cognitive ability.

Conclusions and Future Directions

Our continued program of research seeks to make modest gains toward a noble cause: to identify and better understand a critical set of task features and experimental manipulations that have practically and theoretically important influences on multitasking performance, and to link these features and manipulations to individual characteristics and behavioral processes that are cognitive, motivational, personality and interest based. Given our start at a definition of multitasking performance as presented in this report, along with a broad conceptual framework adapted from the job performance literature, we and other researchers can continue our work in addressing many useful research questions related to multitasking performance. For example, what ability-related and non-ability-related strategies are most effective for dealing with demands of multitasking environments, and do certain individuals, such as older individuals (e.g., Salthouse, Hambrick, Lukas, & Dell, 1996), those with low levels of working memory capacity (e.g., Sit & Fisk, 1999) or those with high levels of neuroticism, profit more by adopting certain strategies than other individuals? Or as another example, can physiological measures (e.g., heart rate as an index of anxiety) help refine our understanding of the processes through which personality traits (e.g., neuroticism) influence multitasking performance?

Research questions such as these will generate data pertaining to multitasking performance and performance change over time can profit from advanced statistical techniques such as latent-growth curve modeling and hierarchical linear modeling. Statistically, these techniques can model multitasking

performance and how it changes over time, at the same time incorporating individual-differences measures as predictors of performance and performance change. Both the conceptual and statistical work in this area might increase our basic scientific understanding of multitasking, which has become a pervasive aspect of the modern world. On a more practical note, we are pursuing this line of research to inform and improve personnel selection, classification, and training in applied settings, given multitasking-related jobs where workers must concurrently monitor multiple systems that are relatively independent of one another, and execute quick decision making and planning. Given the thrust of this work, we also hope the work presented here provides some insights related to ability and non-ability predictors of student performance in complex problem-solving environments.

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